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Prospects for Observing Higgs in $ZH \rightarrow (\nu\bar{\nu}, l^+l^-)b\bar{b}$ Channel at TeV33

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ABSTRACT

We report the feasibility study of observing associated production of Higgs and Z^0 bosons with $H \rightarrow b\bar{b}$ and $Z^0 \rightarrow \nu\bar{\nu}, l^+l^-$ at $\sqrt{s} = 2$ TeV high luminosity Tevatron (TeV33). The signature of such decay is a resonance of two b tagged jets, plus either large missing E_t ($E_T > 35$ GeV) or dilepton pair mass near the Z^0 mass. The signal and backgrounds are estimated using the CDF II detector configuration and the numbers are cross checked against the existing CDF Run I E_T data. It may be possible to detect a Standard Model Higgs boson mass up to 120 GeV with $30 fb^{-1}$ of integrated luminosity by combining a result with $W^\pm H \rightarrow l^\pm \nu b\bar{b}$ channel.

I. INTRODUCTION

Several studies in past [1, 2, 3] have shown that there are significant potential of observing associated production of Higgs and Z^0 boson with $Z^0 \rightarrow \nu\bar{\nu}$ and $H \rightarrow b\bar{b}$ because of large decay branching ratios, $Br(Z^0 \rightarrow \nu\bar{\nu}) = 19.2\%$ and $Br(H \rightarrow b\bar{b}) = 83\%$ for Higgs mass below 120 GeV. However, it remains to be seen whether a simple trigger and a set of selection requirements exists besides b -tagging which could reduce most of the QCD background while maintaining a significant portion of signal. In this note, we are going to investigate the experimental sensitivity to $Z^0 H$ production at TeV33 and to estimate the size of signal and backgrounds. Throughout this study we use Monte Carlo events generated with Pythia event generator and simulated with current CDF fast detector simulation, QFL. For the tracking and b -tagging at large η , we just tag the b jet at the generator level and apply the tagging efficiency measured in the central region, which will be discussed later. For background samples, we consider standard model $Z^0 + b\bar{b}$, $Z^0 + c\bar{c}$, $Z^0 Z^0$, $t\bar{t}$ production, single top and mistags. Both signal and backgrounds are normalized to $30 fb^{-1}$ at $\sqrt{s} = 2$ TeV.

This note is organized as follows: in Sec. II, we optimize b -tag and other kinematic selection criteria using the CDF Silicon Vertex b -tagger (SECVTX) and the soft lepton b -tagger (SLT). In Sec. III, we review the detector acceptance and background estimations. Finally, we conclude in Sec. IV.

II. B -TAGGING EFFICIENCY AND OTHER KINEMATIC SAMPLE SELECTIONS

The ability to tag b jets with high efficiency and low mistag rate is vital for searching for the decay of $H \rightarrow b\bar{b}$. The

technique for b -tagging has been well established in CDF using the Silicon Vertex tagger (SECVTX) and the Soft-Lepton tagger (SLT) [4], but will be much improved in the CDF II upgrade tracking [5]. The full 3-D silicon tracker will eliminate a large fraction of mistags, allowing greater efficiency. The standalone pattern recognition in the silicon tracker itself will allow b tagging to extend into the $1 < |\eta| < 2.0$ region. To be conservative, we are going to use the same b tag efficiencies and mistag rate per jet inside the SVX fiducial region measured in the CDF Run I data which are shown in Figure 1. The tight b -tagger is the default CDF secondary vertex tagger (SECVTX). The loose b -tagger includes the SLT tags with $P_T > 2.0$ GeV and the jet-probability tags with less than 2%, which uses a track's signed impact parameter to determine the probability that the jet is consistent with originating from the primary vertex. The loose b tagger increases the tagging efficiency on b/c /fakes by 23%, 50% and 100%, respectively. In our Higgs search, we require at least one of two b jets passing the tight cut.

For the $Z^0 H \rightarrow \nu\bar{\nu} b\bar{b}$, in order to further reduce the large QCD backgrounds in missing E_t ($E_T > 35$ GeV) sample, we apply the following kinematic selection criteria:

- Raw $E_T > 35$ GeV to pass the trigger requirement.
- Two b tagged jets with $E_t > 15$ GeV in $|\eta| < 2.0$.
- Minimum $\delta\phi_{min} > 0.5$ between E_T and any jets $E_t > 8$ GeV and $|\eta| < 2.0$.
- No extra jet $E_t > 8$ GeV in $|\eta| < 2.4$.
- Significance of $\sigma_{\mathcal{P}_T} = E_T / \sqrt{E_{t,jet1}} > 5$, where the $E_{t,jet1}$ is the corrected E_t of first jet.
- No isolated track above 10 GeV in the events, where the isolation requirement is $\Sigma Pt < 2.0$ GeV over the additional tracks inside the cone 0.4.

The above selection cuts are optimized in the CDF Run I missing E_t ($E_T > 35$ GeV) data as a background and a $Z^0 H$ signal Monte Carlo sample. For example, the comparison of $\delta\phi_{min}$ and E_T distribution between signal and background is shown in Figure 2. The E_T in the background sample are predominately due to mismeasured jets resulting in the E_T direction being aligned along with the jet direction while the $\delta\phi_{min}$ in the signal sample is flat.

In the $Z^0 H \rightarrow (e^+e^-, \mu^+\mu^-)b\bar{b}$ channel, we select the dilepton events with the following cuts.

- First lepton $E_t(Pt) > 20$ GeV, $|\eta| < 1.0$
- Second lepton $E_t(Pt) > 10$ GeV, $|\eta| < 2.0$
- $|M_{Z^0} - M_{l^+l^-}| < 15$ GeV
- Two b -tagged jets with $E_t > 15$ GeV and $|\eta| < 2.0$

III. SIGNAL AND BACKGROUND YIELDS

A. Signal Yields

Applying the b tag efficiencies and kinematic selections to the Z^0H and $W^\pm H$ Monte Carlo samples, the resulting acceptance and number of observed events are shown in Table I assuming 30 fb^{-1} of integrated luminosity with the latest theoretical cross section calculation[6]. The $W^\pm H$ process contributions to the $Z^0H \rightarrow \nu\bar{\nu}b\bar{b}$ cross section by 10% when the lepton from W decay is missed. For a Higgs mass of $110 \text{ GeV}/c^2$, the acceptance is about 2.1% including the decay branching ratios. We expect 49/25/8 events from $Z^0H \rightarrow \nu\bar{\nu}b\bar{b}$, $Z^0H \rightarrow (e^+e^-, \mu^+\mu^-)b\bar{b}$ and $WH \rightarrow \cancel{E}_T b\bar{b}$, respectively. The mass resolution of $H^0 \rightarrow b\bar{b}$ is estimated to be 14 GeV. For the significance study, we integrate the background over the dijet mass bins $\pm 28 \text{ GeV}$ about M_H .

B. Backgrounds Yields

The background events are predominantly from directly produced $Z^0b\bar{b}$, Z^0Z^0 , single top($W^* \rightarrow tb$) and $t\bar{t}$. Other backgrounds from mistags due to track confusion, $Wb\bar{b}$ and $W^\pm Z^0$ due to missing W decay are found to be small. For Z^0 plus heavy flavor we use HERWIG Monte Carlo sam-

Table I: The expected Z^0H signal and background events as a function of Higgs Mass in 30 fb^{-1} at TeV33.

$M_H \text{ (GeV}/c^2\text{)}$	90	100	110	120
$\sigma_{Z^0H} \text{ (pb)}$	0.24	0.18	0.13	0.1
$\epsilon_{Z^0H} \text{ (%)}$	1.5	1.7	2.1	1.7
Signal evt(S):	108	92	82	51
Backgrounds				
(a) $Z^0 + \text{h.f.}$	290	250	216	190
(b) Z^0Z^0	176	168	151	110
(c) $W^* \rightarrow tb$	40	46	47	47
(d) $t\bar{t}$	27	31	31	31
Total Bkg(B)	533	495	462	378
Significance ($S/\sqrt{S+B}$)	4.3	3.8	3.5	2.5

ples to calculate the fraction of events expected from the gluon splitting processes and $gg \rightarrow Z^0b\bar{b}$ in $Z^0+2\text{jet}$ bins and their tagging efficiencies. The number of background events is then obtained as the product of these quantities times the expected $Z^0+2\text{jet}$ events at TeV33. The background process Z^0Z^0 with $Z^0Z^0 \rightarrow (\nu\bar{\nu}, l+l^-)b\bar{b}$ is es-

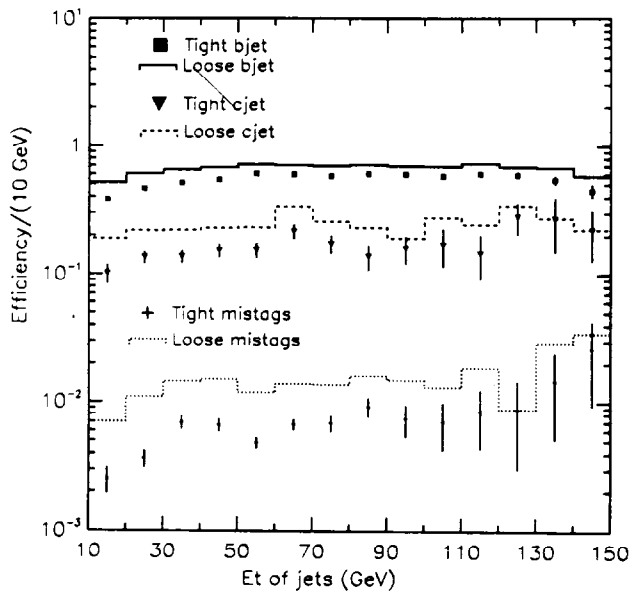


Figure 1: The SVX b/c/fakes tagging efficiency per jets inside the SVX fiducial region both for tight and loose cuts described in the text.

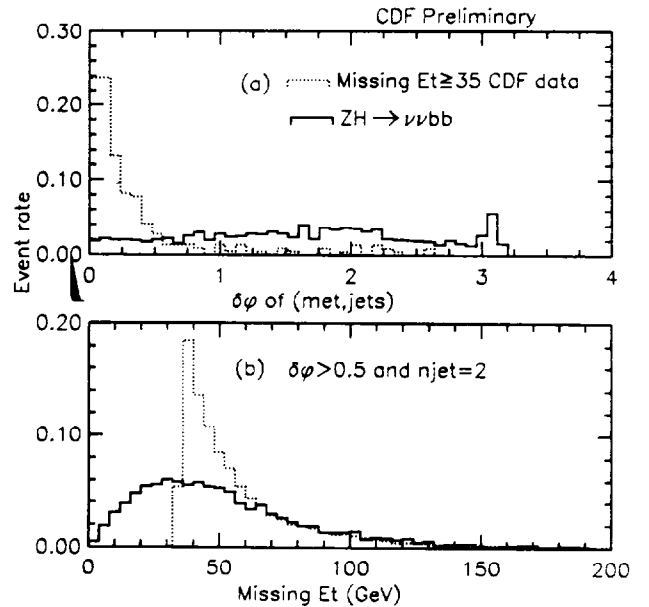


Figure 2: The comparisons of (a) minimum $\delta\phi$ between \cancel{E}_T and any jets ($Et > 8 \text{ GeV}$ and $|\eta| < 2.0$) and (b) \cancel{E}_T in the CDF Run I \cancel{E}_T sample and $Z^0H \rightarrow \nu\bar{\nu}b\bar{b}$.

estimated using PYTHIA and CDF QFL simulation, which can be measured directly from the all leptonic decay of diboson. The remain backgrounds from $t\bar{t}$ and single top are estimated using Pythia and CDF QFL simulation, normalized the $t\bar{t}$ cross section as $\sigma_{t\bar{t}} = 7.6 \pm 1.9 \text{ pb}$, measured by CDF[7]. The single top cross section is taken from theory [6]. The results are shown in Table I. We have checked our background calculation using CDF Run I missing Et ($E_T > 35 \text{ GeV}$) and $Z^0 \rightarrow l^+l^- + 2\text{jets}$ samples with two tight b -tagged jets. There are 3 events passing the cuts, which is in good agreement with the expectation of 2.1 events.

C. Significance of Signal

Figure 3 shows the dijet mass spectrum for $H \rightarrow b\bar{b}$ with $M_H = 110 \text{ GeV}/c^2$ superimposed on the expected backgrounds. Each individual background shape can be directly determined from data. For the $t\bar{t}$ contributions, we can determine the $b\bar{b}$ invariant mass distribution in the top dilepton events or fully reconstructed $W+4\text{jets}$. For the $Z^0b\bar{b}$, we could determine the mass shape using untagged events and take into account the possible differences due to b -tagging bias and $Z^0b\bar{b}$ vs inclusive $Z^0+2\text{jets}$. For the $Z^0 \rightarrow b\bar{b}$, we rely on the dijet mass shape predicted from Monte Carlo samples.

The signal after background subtraction is also shown in Fig. 3, which shows an enhancement slightly more than 3σ . We generalize this procedure to determine the significance of this measurement as a function of Higgs mass, shown in Table I. With 30 fb^{-1} of integrated luminosity at TeV33, we will be able to observe Higgs with more than 3σ effect in Z^0H channel only for a Higgs mass up to 110 GeV .

IV. CONCLUSION

We report the feasibility study of observing associated production of Higgs and Z^0 bosons with $H \rightarrow b\bar{b}$ and $Z^0 \rightarrow \nu\bar{\nu}, l^+l^-$ at TeV33. The signature of such decay is a resonance of two b tagged jets, plus either large missing Et ($E_T > 35 \text{ GeV}$) or dilepton pair mass near the Z^0 mass. The signal and backgrounds are estimated using the CDF II detector configuration and the numbers are cross checked against the existing CDF Run I missing Et data. It may be possible to detect a Standard Model Higgs boson mass up to 120 GeV with 30 fb^{-1} of integrated luminosity by combining a result with $WH \rightarrow l\nu b\bar{b}$ channel[3, 8].

V. ACKNOWLEDGEMENTS

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VI. REFERENCES

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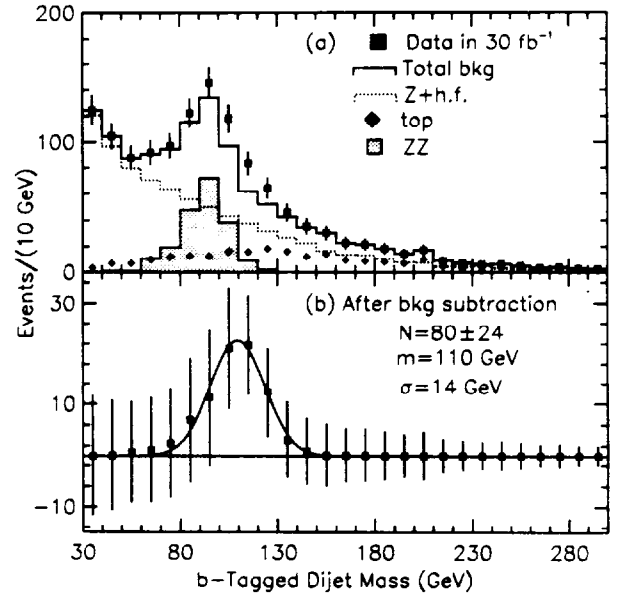


Figure 3: (a) The comparison of b -tagged dijet mass with and without the Higgs signal for $M_H = 110 \text{ GeV}/c^2$ (b) the expected Higgs signal after the perfect background subtraction.